

Habitat heterogeneity and anuran community of an agroecosystem in the Pantanal of Brazil

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Abstract

Habitat heterogeneity and anuran community of an agroecosystem in Pantanal, Brazil. The Pantanal of central Brazil has experienced considerable modifications as a result of growing land use. The association between anuran assemblage and the local habitat structure of an agroecosystem in central Brazil at the Pantanal is described. It is shown that the structure of the anuran community is reestablished within the new environmental dynamics in such human-modified habitat. Twenty-four anuran species were recorded in the area. The community was dominated by four species (*Dendropsophus nanus*, *Leptodactylus chaquensis*, *Hypsiboas raniceps*, and *Rhinella* cf. *bergi*), which accounted for more than 50% of the sampled individuals. The species distribution pattern was adjusted to the logarithmic, log-normal, and broken stick models, partially reflecting its association with agroecosystem characteristics. Habitat heterogeneity contributes to the anuran community at a local scale, thereby emphasizing the importance of maintaining distinct habitats for anuran species in the Pantanal as a management practice, even in situations in which anthropic actions are predictable, as in agroecosystems.

Keywords: agriculture, amphibians, habitat complexity, Pantanal, wetland.

Resumo

Heterogeneidade ambiental e comunidade de anuros em agroecossistema na região do Pantanal, Brasil. A planície pantaneira no Brasil Central tem sofrido intensa modificação devido às práticas de ocupação antrópica ocorrida nos últimos anos na região. Este trabalho ilustra a associação entre a comunidade de anfíbios anuros e a estrutura ambiental em escala local de um agroecossistema no Pantanal (Mato Grosso do Sul) e mostra que em ambientes modificados pela ação humana a comunidade de anuros pode ser restabelecida de acordo com as novas condições encontradas. Foram encontradas 24 espécies de anuros das quais quatro foram predominantes (*Dendropsophus nanus*, *Leptodactylus chaquensis*, *Hypsiboas raniceps* e *Rhinella* cf. *bergi*), representando mais de 50% dos

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indivíduos amostrados. O padrão de distribuição das espécies foi melhor ajustado aos modelos logarítmicos, log-normal e *broken stick*, refletindo parcialmente uma associação com as características do agroecossistema. A heterogeneidade ambiental contribuiu com a estrutura da comunidade, o que reforça a importância da manutenção de ambientes distintos para as espécies de anuros do Pantanal como uma prática de manejo mesmo em situações em que as ações antrópicas forem previsíveis e irreversíveis como os agroecossistemas.

Palavras-chave: agricultura, anfíbios, complexidade ambiental, Pantanal, planície de inundação.

Introduction

Although 946 amphibian species are recorded from Brazil (Segalla *et al.* 2012), there is much to be learned about the ecological factors that shape anuran community structure. Community ecology theory predicts that heterogeneous habitats will have higher species richness than homogeneous habitats at local and regional scales (Tews *et al.* 2004). A well-documented relationship between habitat complexity and species richness is documented for many species, including amphibians (Purrenhage and Bone 2009, Vasconcelos *et al.* 2009, Silva *et al.* 2011).

Agriculture is among the main causes of global loss of biodiversity resulting from expansion of croplands and pastures, as well as land-management practices involving irrigation and the use of fertilizers and pesticides (Foley *et al.* 2011). However, some species seem adapted to living in the marginal transitional zones between agro- and natural ecosystems (Altieri 1999). Several studies of the effects of agroecosystems on biodiversity have appeared in the last decade (Zamora *et al.* 2007, Duré *et al.* 2008, Piatti *et al.* 2010, Piatti and Souza 2011). It has become clear that it is important to distinguish the impacts of agricultural practices as opposed to natural processes on habitats over limited temporal and spatial scales (Benton *et al.* 2003, Hill and Hamer 2004, Jepsen *et al.* 2005). In this way, demographic responses to habitat changes can be associated with the ways in which species deal with the matrix permeability

around natural habitats; depending upon the characteristics of the agroecosystem, the matrix may create severe barriers that affect population dynamics (Ricketts 2001, Benton *et al.* 2003, Weibull *et al.* 2003). In amphibians, there usually is a negative relationship between species diversity and agroecosystems, because the structure of the habitat can influence amphibian distributions along a heterogeneity gradient (Joly *et al.* 2001, Beja and Alcazar 2003, Piha *et al.* 2007). Given their physiological constraints, anuran activities are mediated by favorable microhabitat conditions, such as humidity and shelter (Eterovick and Ferreira 2008, Wachlevski *et al.* 2008, Vasconcelos *et al.* 2009, Silva *et al.* 2011).

In recent decades, the areas adjacent to the Pantanal in central Brazil have been modified by intensified land usage (Harris *et al.* 2006, Dobrovolski *et al.* 2011) that threatens their natural biodiversity. Wetlands throughout the world, including the Pantanal, are diminishing owing to agriculture. Natural wetlands are being functionally replaced by irrigated fields, which harbor many aquatic species, including amphibians (Duré *et al.* 2008, Machado and Maltchik 2010, Piatti *et al.* 2010, Piatti and Souza 2011); however, drainage activities and land management of these aquatic systems are thought to be harmful to anurans (Colombo *et al.* 2008). Thus, any information about the relationship between anuran populations and habitat complexity is strategically important to sound environmental management practice, especially in regions with

high deforestation activities. Herein, we describe the association of an anuran assemblage with local habitat structure in an agroecosystem in the Pantanal and demonstrate that even in such a human-dominated habitat, the structure of an anuran community can be remodeled in harmony with environmental characteristics that are anthropogenically modified.

Materials and Methods

With about 140,000 sq km of low-lying floodplains, the Pantanal is one of the largest wetlands in the world and hosts a rich biodiversity

(Junk *et al.* 2006, Alho 2011). This study was conducted in a farmland area dedicated to irrigated rice production (Fazenda San Francisco; municipality of Miranda, State of Mato Grosso do Sul, central Brazil; 20°05'10" S, 56°36'57" W) located along the southeastern border of the Pantanal (Figure 1). The climate is tropical, and hot and wet (PCBAP 1997), with a well-defined rainy season from October–March and a dry season from April–September. The rice plantation occupies 3,400 ha of a total of 14,000 ha that also includes pastures and native vegetation; the later includes gallery and deciduous forests, as well as distinct cerrado physiognomies. The



Figure 1. The Fazenda San Francisco is located at the south-eastern border of the Pantanal. Sinuous line at north indicates the Miranda River, which defines the natural limit of the area. The well-defined rectangles at center correspond to rice fields. Light areas correspond to pastures and dead vegetation while forest areas are gray. The white lines correspond to rice fields maintenance roads. Dots illustrate the location of the 40 sampled units.

rice plantation is composed of several 40 ha quadrats (200 × 2000 m) interconnected by local roads and drainage channels (2–10 m wide and 0.5–1.5 m deep), which are supplied with water by the Rio Miranda (Piatti *et al.* 2010, Piatti and Souza 2011). Aquatic vegetation, herbaceous plants, and small trees grow along the banks of the drainage channels (Figure 1).

Sampling was carried out monthly during both the dry and the rainy seasons from April 2007–March 2008. Anurans and habitat heterogeneity were surveyed in 40 randomly sampled quadrats (50 × 50 m; as described by Krebs 1999) in the farm area (Figure 1). Quadrats were separated by a minimum of 500 m to avoid spatial pseudo-replication. Two researchers actively searched (Heyer *et al.* 1994) each quadrat from 10:00–16:00 h and from 18:00–23:00 h to sample diurnal and nocturnal species. All the specimens found below a height of 4 m on the vegetation were captured, identified, and kept in plastic bags until quadrat sampling was completed. Captured individuals were released at least 1 km away from the sampled quadrats to avoid pseudo-replication and the consequent overestimation of the frequencies of the species (Piatti *et al.* 2010). Voucher specimens were euthanized with xylocaine, fixed in 5% formalin, and transferred to 70% alcohol. Specimens were deposited at the Coleção Zoológica de Referência da Universidade Federal de Mato Grosso do Sul (ZUFMS, Campo Grande, Mato Grosso do Sul State; voucher numbers: AMP00967, AMP01079-01081, AMP01083, AMP01087, AMP01089, AMP01097-01098, AMP01106-01108, AMP01110, AMP01124-01126, AMP01132-01134, AMP01136, AMP01139, AMP01146). Collecting activities were permitted by ICMBio process number 10379.

The predicted species richness for the area was assessed by sampled-based rarefaction curves for the 40 quadrats with EstimateS 8.0 (Colwell 2009) with 1000 randomizations of the original field samples employing the non-parametric Jackknife 1 index. The species abundance distribution pattern was assessed with a

Chi-square test on the geometric, logarithmic, log-normal, and broken stick abundance distribution models to check for the better adjustment to the observational data (Magurran 2004) with Bio-Dap (Thomas and Clay 2000).

Twenty-five 10 × 10-m grids were established for each of the 40 sampled quadrats; five quadrats were randomly chosen to assess habitat heterogeneity variables that included pasture field, rice field, naked soil, dead vegetation (shrubs and fallen trees), understory vegetation (shrubs and vines), litter, water cover, and aquatic vegetation. The relationship between anurans and these habitat characteristics was tested using a Canonical Correspondence Analysis, CCA (Ter Braak 1986); this multivariate approach associates species assemblage (dependent variable) with habitat characteristics (independent variables) throughout the respective data matrices. In this analysis, the association between habitat characteristics and abundance of particular anuran species was predicted. In the CCA, each quadrat sampled included measures for habitat characteristics, whereas the species matrix consisted of the number of individuals (Vitt *et al.* 2007). The CCA analysis was performed using the software PAST (Hammer *et al.* 2001) based on a Monte Carlo test with 1000 permutations.

Results

A total of 1721 individuals representing 24 anuran species of five families were recorded from the 40 sample quadrats of Fazenda San Francisco, as follow: Bufonidae: *Rhinella* cf. *bergi* and *R. schneideri*; Hylidae: *Dendropsophus nanus*, *Hypsiboas punctatus*, *H. raniceps*, *Phyllomedusa azurea*, *P. sauvagii*, *Pseudis limellum*, *P. platensis*, *Scinax acuminatus*, *S. nasicus*, and *Trachycephalus typhonius*; Leiuperidae: *Eupemphix nattereri*, *Physalaemus albonotatus*, *P. centralis*, *P. cuvieri*, and *Pseudopaludicola* sp.; Leptodactylidae: *Leptodactylus chaquensis*, *L. diptyx*, *L. elenae*, *L. fuscus*, and *L. podicipinus*; Microhylidae: *Dermatonotus muelleri* and *Elachistocleis bicolor*.

Rarefaction curves suggested the occurrence of 24 anuran species in the area, with the tendency to reach the asymptote after sampling 10 quadrats (Figure 2). The community was dominated by four anuran species (*Dendrosophus nanus*, *Hypsiboas raniceps*, *Leptodactylus chaquensis*, and *Rhinella* cf *bergi*) representing more than 50% sampled individuals, whereas species such as *Physalaemus cuvieri* and *Dermatonotus muelleri* were less abundant (Figure 3). The species abundance distribution pattern was adjusted to all except the geometric model (Table 1).

According to the CCA analyses, there is a significant association between agroecosystem habitat structure and anuran community (eigenvalue = 0.329, $P < 0.01$). *Pseudis platensis*, *P. limellum*, *Dendrosophus nanus*, and *Leptodactylus fuscus* were associated with aquatic habitats and aquatic vegetation; *Elachistocleis bicolor*, *Phyllomedusa azurea*, and *P. sauvagii* were associated with pastures and shrubs; *Leptodactylus podicipinus*, *Pseudopaludicola* sp., and both species of *Rhinella* were associated with rice fields. *Physalaemus albonotatus*, *Leptodactylus diptyx*, *Eupemphix nattereri*, *Trachycephalus typhoni*, *Scinax nasicus*, *Hypsiboas punctatus*, and *H. raniceps* were associated with areas dominated by forests characterized by abundant litter; *Leptodactylus elenae* was found in areas with dead vegetation and naked soil, whereas *Leptodactylus cha-*

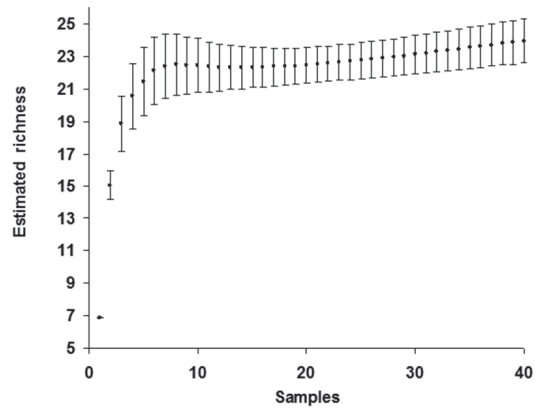


Figure 2. Rarefaction curve for anurans from the Fazenda San Francisco, Mato Grosso do Sul State, Central Brazil. The curve represents mean richness (bars denote standard deviations) estimated by Jackknife 1 method after 1,000 randomizations of the 40 sample units verified from April 2007 to March 2008.

quensis and *Scinax acuminatus* were associated in transitional areas with water and shrub vegetation (Figure 4).

Discussion

The 24 species of the anuran assemblage from Fazenda San Francisco represent approximately 40% of the anuran community associated with the Pantanal floodplains and

Table 1. Chi-square adjust analyses for the species abundance distribution models considered for the anuran community from Fazenda San Francisco agroecosystem, Mato Grosso do Sul State, Central Brazil. A P value < 0.05 refers to significant difference between the observed and the expected species abundance distribution model.

Models	Degrees of freedom	Chi-square	P
Geometric	21	275.4	< 0.05
Logarithmic	21	20.8	> 0.05
Log-normal	21	2.95	> 0.05
Broken stick	21	2.05	> 0.05

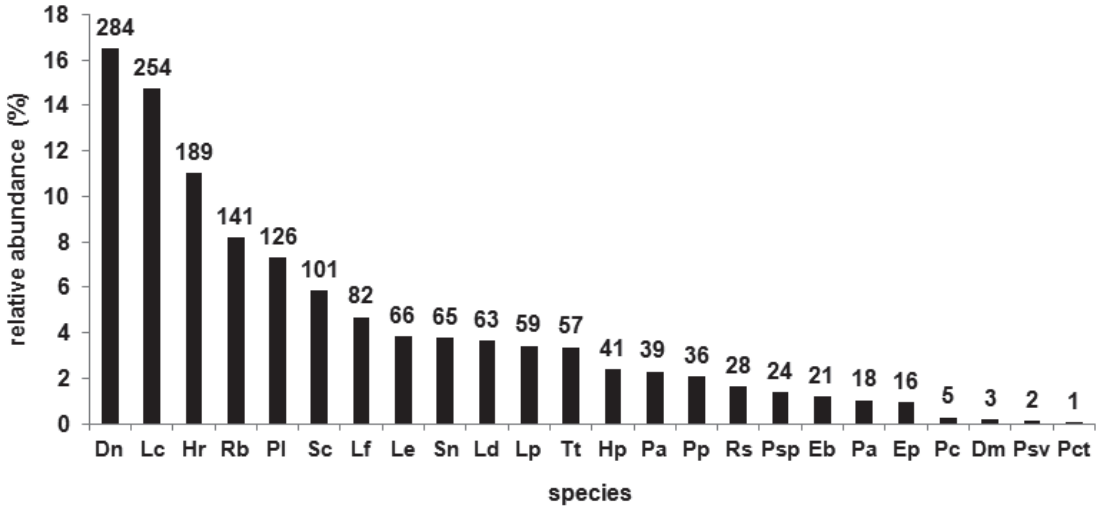


Figure 3. Relative abundance of the 24 anuran species sampled between April 2007 and March 2008 from Fazenda San Francisco, Mato Grosso do Sul State, Central Brazil. Values above bars indicate the number of individuals sampled for each species (Dn: *Dendropsophus nanus*; Lc: *Leptodactylus chaquensis*; Hr: *Hypsiboas raniceps*; Rb: *Rhinella cf bergi*; Pl: *Pseudis limellum*; Sc: *Scinax acuminatus*; Lf: *Leptodactylus fuscus*; Le: *Leptodactylus elenae*; Sn: *Scinax nasicus*; Ld: *Leptodactylus diptyx*; Lp: *Leptodactylus podicipinus*; Tt: *Trachycephalus typhonius*; Hp: *Hypsiboas punctatus*; Pa: *Physalaemus albonotatus*; Pp: *Pseudis platensis*; Rs: *Rhinella schneideri*; Psp: *Pseudopaludicola* sp.; Eb: *Elachistocleis bicolor*; Pa: *Phyllomedusa azurea*; Ep: *Eupemphix nattereri*; Pc: *Physalaemus cuvieri*; Dm: *Dermatonotus muelleri*; Psv: *Phyllomedusa sauvagii*; Pct: *Physalaemus centralis*).

neighboring areas (Souza *et al.* in press). Although most of the recorded species might be considered habitat generalists (e.g., *Rhinella schneideri*, *Dendropsophus nanus*, *Hypsiboas raniceps*; see Uetanabaro *et al.* 2008), the habitat heterogeneity gradient in the area studied seems to influence the anuran community even in an anthropic-dominated habitat.

The distribution pattern of species abundance in the quadrats was adjusted to the logarithmic, log-normal, and broken-stick abundance distribution models. The log-normal and broken-stick models are characterized by a homogeneous distribution of species abundance whereas the logarithmic model is associated with a community dominated by few common species

and a great diversity of rare species (Magurran 2004). Interspecific competition is thought to reflect affect a geometric series abundance distribution model by limiting or excluding niche overlap (Magurran 2004). However, this prediction is not usually apparent in open-area anuran communities, such as those that occur in agroecosystems, which usually are characterized by high temporal and spatial niche overlap (Duré *et al.* 2008, Santos *et al.* 2008, Piatti *et al.* 2010). In contrast, the log-normal distribution model, which describes a more equitable representation of species, is found in most of the communities in which assemblages are dominated by many ecological factors other than competition and resource availability. The logarithmic model

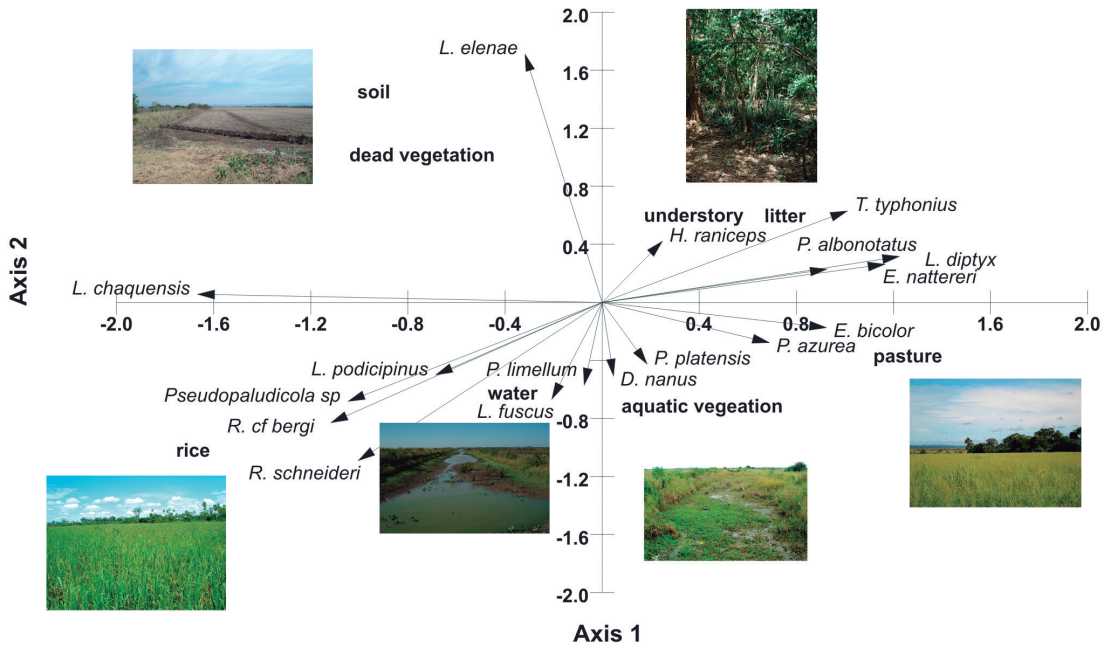


Figure 4. Association between habitat characteristics and anuran abundance matrices from Fazenda San Francisco, Mato Grosso do Sul State, Central Brazil, represented by a Canonical Correspondence Analysis. The plot shows the position of each anuran species among clusters on first two canonical axes. The arrows represent the direction of maximum change of the variable across the diagram and the length of the arrow is proportional to the rate of change. The position of the species in relation to the arrows indicates the environmental preference (illustrated by the photographs).

characterizes communities influenced by few factors and many uncommon species (Magurran 2004). Some species recorded here are classified as open-area dwellers that benefit from anthropic habitats edges, thereby partially reflecting the agroecosystem characteristics and the consequent distribution model fit. Separated analyses of local communities from habitats with distinct heterogeneity gradients, including rice fields, pastures, and forests patches, may generate interesting information about ecological interactions among species inhabiting this agroecosystem.

Habitat heterogeneity in agroecosystems can influence anuran community structure in agricultural landscapes (Guerry and Hunter 2002,


Gardner *et al.* 2007, Silva *et al.* 2011), even though fundamental structures, such as fallen trees and burrows, can contribute in a more predictive way at local scales (Tews *et al.* 2004). The habitat variables representing the habitat heterogeneity selected in this study seem to affect the anuran community at a local scale. Species usually associated with forest habitats, such as *Trachycephalus typhonius*, *Leptodactylus diptyx*, and *L. elenae* (Uetanabaro *et al.* 2008), were recorded in plots characterized by a remarkably heterogeneous habitat structure, represented by riparian forest and forest fragments. In contrast, *Rhinella* spp., *Pseudopaludicola* sp., and *Elachistocleis bicolor* inhabit humid and open areas in cerrado (Uetanabaro *et*

al. 2008) and were captured in pastures and rice fields, which are homogeneous habitats. *Dendropsophus nanus* also efficiently uses rice fields. Given the high species abundance, rice agriculture apparently favors anuran species, operating as a substitutive for natural perch habitats. Aquatic species such as *Pseudis platensis* and *P. limellum* were recorded in those areas with flooded rice fields and drainage channels. These are common representatives from aquatic habitats throughout the Pantanal (Uetanabaro *et al.* 2008) and have successfully colonized rice fields and neighboring humid areas (Piatti *et al.* 2010). These findings suggest that population dynamics in the area are affected by local processes related to land use by humans, such as river drainage and forest logging for pasture and agricultural fields. Land management, along with natural flooding, increase availability of humid habitat in the area. The Rio Miranda is the main source of water from which artificial flooding occurs through systems of drainage channels (Piatti *et al.* 2010, Piatti and Souza 2011). Thus, water is not a limiting resource in this agroecosystem. The presence of full water drainage channels year round creates available humid habitats along the edges of the area and might minimize the impact of seasonal variation on the anuran community; thus, anuran communities in the area may be less sensitive to seasonality of humid areas in environments dominated by rice agriculture.

In the future, expansion of agriculture activity likely will affect biodiversity on a global scale (Dobrovolski *et al.* 2011). Given that agroecosystem landscapes are expanding, it is critical to recognize these new human-created habitats as a research focus in contemporary ecological studies (Martin *et al.* 2012). Isolated or interacting factors such as ultraviolet radiation, global climatic change, pollution, diseases, and exotic species are thought to affect amphibian populations (see Silvano and Segalla 2005). However, habitat loss and fragmentation are considered the main causes of amphibian extinction at local and global scales (Becker *et*

al. 2007, 2010). Thus, maintenance of ecosystem integrity and habitat connectivity may be crucial for amphibian conservation strategies (Becker *et al.* 2010). The Pantanal is one of the largest wetlands of the world; its ecosystem service and biodiversity are under constant threat, given the diverse land-use activities in the region (Alho and Sabino 2011). One of the major priorities for areas under anthropogenic pressure in the Pantanal is the maintenance and protection of key habitats, such as forests and water bodies (Alho and Sabino 2011). The results presented herein emphasize the importance of habitat heterogeneity for anuran species in the Pantanal as a management practice, even in those situations in which anthropic actions are unavoidable such as the agroecosystems.

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